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Measurement properties of step tests for exercise capacity in COPD: A systematic review

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Abstract

Objective: To determine the level of evidence of the measurement properties (validity, reliability, and responsiveness) and interpretability of the step tests available for assessing the exercise capacity in patients with chronic obstructive pulmonary disease.

Data sources: The data sources Web of Science, MEDLINE, PubMed, PEDro, CENTRAL of Cochrane Library, and Scopus were searched up to June 26, 2020.

Review methods: Studies of any design that reported results for any measurement property of the step tests for assessing the exercise capacity in COPD patients were selected. One reviewer extracted the data, and two reviewers independently rated the level of evidence by using the Consensus-Based Standards for the Selection of Health Measurements Instruments recommendations.

Results: Thirty-one studies were included in the data synthesis. Chester Step Test, Modified Incremental Step Test, two-, three-, four-, and six-Minute Step Test, Paced Step Test, and six-Minute Stepper Test were identified. A step test protocol was also found. The level of evidence of their results for the measurement properties was mostly determined as "low" to "very low." The best level of evidence found was for the six-minute stepper test: "high" on construct validity ($r = 0.56–0.71$); and "moderate" on criterion validity ($r = 0.36–0.69$), and responsiveness ($r = 0.26–0.34$).

Conclusion: The general level of evidence of the measurement properties of the step tests is "low" to "very low" for assessing exercise capacity in patients with chronic obstructive pulmonary disease, which can limit their application in clinical practice. The six-minute Stepper Test is currently the most appropriate step test available.

Keywords

Step testing, validity, reliability, responsiveness, pulmonary rehabilitation

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Introduction

The assessment of exercise capacity is an important clinical measure of the functional status in people with chronic obstructive pulmonary disease.[1] It is defined as one's physiological maximal response to exercise, including the exercise tolerance tests, or the body structure's maximal ability to fulfill its function, including the measurement of maximal muscle contractions.[2] The gold standard tests used for its assessment are the cardiopulmonary exercise testing, on a treadmill or a cycloergometer,[3] and the one-repetition maximum.[4] Additionally, in pulmonary rehabilitation, the field walking tests are also considered valid options, especially the six-minute walk test and the incremental or endurance shuttle walk test.[2,5]

However, these mentioned tests require a large amount of space, aside from the expensive equipment for the cardiopulmonary exercise testing,[3,5] which may limit their application in the new models of pulmonary rehabilitation suggested in the literature, like the community- and home-based programs.[6] These new models are important strategies to enhance population access to pulmonary rehabilitation services, from the moment that their benefits are already comparable to those obtained with the hospital-based.[7,8] Also, as a result of this time of COVID-19 pandemic, the transition of the hospital services to community and home is necessary,[9] and, for that, the search for tests with minimal space requirements for exercise testing is necessary.

The step testing could be a promising tool, as it requires less physical space, the equipment is feasible, and it is representative of the daily activities (stair climbing). A wide variety of step tests have been described not only with different equipment, such as the use of a step or a stepper,[10] but also with different aims, according to the self-paced, constant, or externally paced work rate. In a recent review, to identify exercise tests that are suitable outside the traditional hospital-based pulmonary rehabilitation programs, step testing was considered a useful resource in people with chronic respiratory diseases.[9]

In chronic obstructive pulmonary disease, the identification of the measurement properties and the interpretability of step testing have been analyzed in the last years,[11,12] however, it is important to assess the quality of the current level of evidence of the measurement properties before the full implementation of the step testing in clinical practice. Therefore, this study aimed to determine the level of evidence of the measurement properties (validity, reliability, and responsiveness) and interpretability of the step tests available for assessing the exercise capacity in people with chronic obstructive pulmonary disease.

Methods

This systematic review was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines (PRISMA),[13] and was registered in the International Prospective Register of Systematic Reviews (PROSPERO) (CRD42020155872).

The literature search was conducted in the following electronic databases: Web of Science, MEDLINE, PubMed, Physiotherapy Evidence-Based Database, Cochrane Central Register of Controlled Trials, and Scopus. The search was performed between 21st and 26th of June 2020. The key terms used were "step test," "stepper test," "stepping," "COPD," and "chronic obstructive pulmonary disease." The search strategy is available in Supplemental Appendix 1.

For this review, a step test was defined as a test where people are instructed to step up and down on a platform (step or stepper) with a specific height, and in a self-paced and/or externally paced work rate. Studies of any design that reported results for any measurement property (validity, reliability, responsiveness), and interpretability of the step tests for assessing the exercise capacity in people with chronic obstructive pulmonary disease were selected. For this review, we assumed the identification of the step tests that provided the maximum amount of physical exertion that a patient can sustain according to the aim of each test. Another important inclusion criterion was the diagnosis of the chronic obstructive pulmonary disease based on the Global Initiative for Chronic Obstructive Lung Disease criteria.[14] Studies not written in English or Portuguese, published in non-indexed journals and abstracts in conference proceedings were excluded. One reviewer (R.V.) performed the initial screening of the articles based on type of publication and relevance for the review. Then, the full-text of each relevant study was screened for content to decide its eligibility. Selection of studies was checked by a second reviewer (A.M.M.).

Data extraction focused on the measurement properties (validity, reliability, and responsiveness) and interpretability defined according to the Consensus-Based Standards for the Selection of Health Measurements Instruments (COSMIN) definitions (Supplemental Appendix 2).[15–17] For criterion validity, we assumed the comparisons of the step tests with the cardiopulmonary exercise testing and the one-repetition maximum, considered the gold standard measures for exercise capacity.[2] For construct validity, we considered the comparisons with the six-minute walking test, incremental shuttle walk test, endurance shuttle walk test, and other tests available to assess muscle strength. For reliability, studies of test-retest reliability or of measurement error were considered. On the other hand, for responsiveness, we considered the studies that used the step tests to analyze the effects of any intervention, with changes over time and through comparisons with changes in other outcomes. The interpretability was included according to the qualitative meaning of the tests, for example, with norm scores and minimal important difference.[18] According to Schunemann et al., minimal important difference provides the smallest change in the outcome of interest that patients perceive as important, either beneficial or harmful, and that would lead the patient or clinician to consider a change in management.[19]

The methodological quality of the studies included was assessed by the Consensus-Based Standards for the Selection of Health Measurements Instruments risk-of-bias checklist (box 6, 7, 8, 9, and 10), based on a rating score system of four-point rating scale ("very good," "adequate," "doubtful" or "inadequate").[15] For each study, the score per box is obtained by taking the lowest rating of any item in a box. According to the recommendations by Terwee et al.,[20] we assumed for the reliability and measurement error studies, that the step tests conducted on the same day were not appropriate (item 2 of box 6 and 7). Furthermore, the studies on responsiveness that used only the paired sample T-test or Wilcoxon signed-rank test to measure significant changes were also not appropriated (item 6, 9, and 12 of box 10).[21]

Another rating was performed for the quality of the measurement properties using the rating system proposed by Terwee et al.,[22] where one or more criteria was used to define a "sufficient" (+), "indeterminate" (?) or "insufficient" (−) rating depending on the designs, methods, and outcomes of the studies. The definition and criteria for each measurement property are described in Supplemental Appendix 2.

After rating the methodological and measurement properties qualities, the modified Grading of Recommendations Assessment, Development, and Evaluation (GRADE) approach was applied to grade the level of evidence, as "high," "moderate," "low," or "very low."[15] The level of evidence was based in four factors: risk of bias, inconsistency, imprecision, and indirectness.[15]

For all ratings, each study was reviewed and assessed by two independent investigators (R.V. and A.M.M.) and discordances in scoring between the two reviewers were resolved by consensus. Some studies were analyzed in more than one measurement property and, in this case, the quality assessment and data extraction of each property were made separately.

Consensus-Based Standards for the Selection of Health Measurements Instruments has no scoring system for interpretability.

Descriptive synthesis of the types and the characteristics of the step tests identified was conducted. Besides, in each study, the name of the authors, country, the published year, measurement properties assessed, sample characteristics (number of participants and age), study aims, and the outcomes measures were retrieved. To determine each measurement property on each step test identified, we also summarized its quality and level of evidence.

Results

The literature search provided a total of 856 records. After duplicates were removed, 637 records were screened for content through title and abstract.

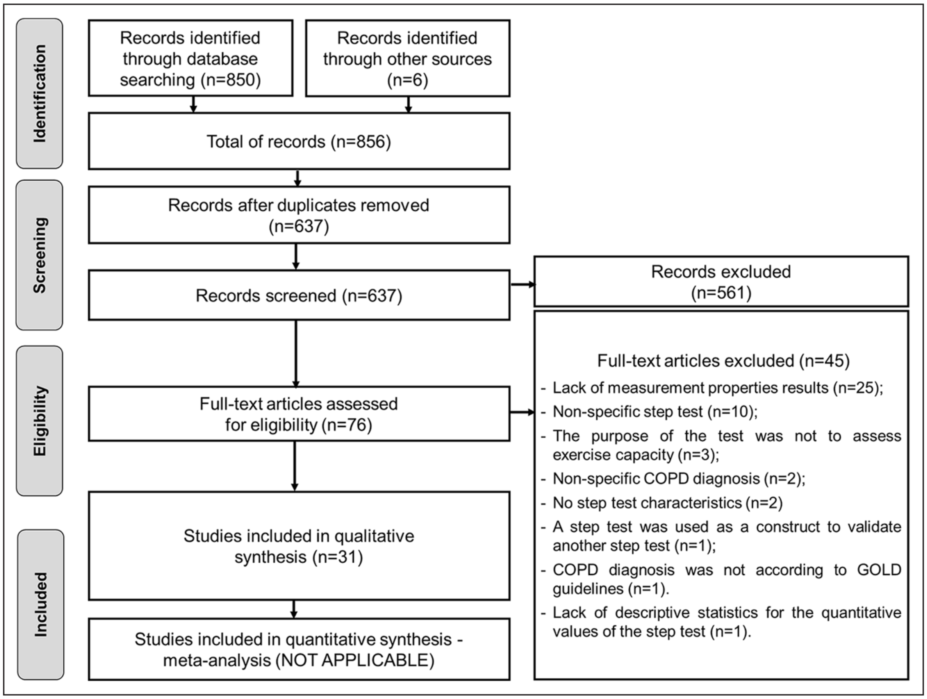

Figure 1. Flowchart of the study.
COPD: chronic obstructive pulmonary disease; GOLD: global initiative for chronic obstructive lung diseases.

From these, 561 were excluded. The full-text of 76 articles was assessed for eligibility and 45 articles were excluded. In total, 31 articles were included (Figure 1) all published in English. The studies were conducted in South America – Brazil ($n=11$), North America – Canada ($n=3$), and Europe – France ($n=14$), Ireland ($n=1$), the Netherlands ($n=1$), and United Kingdom ($n=1$). The flowchart of the study is presented in Figure 1.

The tests identified were the Chester Step Test,[23] Modified Incremental Step Test,[24] two-minute Step Test,[25] three-minute Step Test,[26] four-minute Step Test,[27] six-minute Step Test,[28] Paced Step Test,[29] and six-minute Stepper test.[10] A Step Test Protocol was also included.[30] The characteristics of the tests are available in Table 1.

Eleven articles included validity,[29,31–40] seven articles included reliability,[30,31,33,35,41–43] 13 articles included responsiveness,[36,37,43–53] and five articles included interpretability[33,34,37,54,55] of the step tests. Details on each article included in this review are presented in Supplemental Appendix 3.

For each step test identified, the summary result of the measurement properties and the overall level of evidence, according to the modified Grading of Recommendations Assessment, Development, and Evaluation approach, are presented in Table 2.

Criterion validity was evaluated for the Chester Step Test,[31] Modified Incremental Step Test,[33] Paced Step Test,[29] and six-minute Stepper Test[36,38,39] by comparison with the cardiopulmonary exercise testing. The six-minute Stepper Test also presented a comparison with the quadriceps one-repetition maximum.[40] Construct validity was evaluated for the Chester Step Test,[31,32] three-minute Step Test,[35] six-minute Step Test,[34] and six-minute Stepper Test[36,37,39] by comparison with the six-minute walk test. The Chester Step Test also presented a comparison with the Incremental shuttle walk test.[32]

On reliability, the Modified Incremental Step Test and the Step Test Protocol were the only tests with an appropriate time interval,[30,33] with tests conducted on different days.

Table 1. Characteristics of the step and stepper tests identified.

Name of the test	Characteristics					
	Stages	Initial work rate	Increments	Duration	Profile	Original reference
CST	5 stages	15 steps/min	5 steps/min (every 2 min)	10 min	Incremental	Sykes et al.[23]
MIST	–	10 steps/min	1 step/min (every 30 sec)	Up to the limit of tolerance	Incremental	de Andrade et al.[24]
2MST	–	Free work rate (targeting the maximum number of steps)		2 min	Self-paced	Rikli et al.[25]
3MST	–	Free work rate or externally paced stepping rates (targeting the maximum number of steps)		3 min	Self-paced or constant	YMCA[26]
4MST	–	Free work rate (targeting the maximum number of steps)		4 min	Self-paced	Stephan et al.[27]
6MST	–	Free work rate (targeting the maximum number of steps)		6 min	Self-paced	Dal Corso et al.[28]
Paced step test	–	Stepping every four seconds		Up to the limit of tolerance	Constant	Swinburn et al.[29]
Step test protocol	4 stages	4 stages of three-minute (18, 22, 26, and 32 steps/min)		12 min	Constant	Perrault et al.[30]
6MSpT	–	Free work rate (targeting the maximum number of steps)		6 min	Self-paced	Borel et al.[10]

CST: Chester step test; MIST: modified incremental step test; 2MST: two-minute step test; 3MST: three-minute step test; 4MST: four-minute step test; 6MST: six-minute step test; 6MSpT: six-minute stepper test.

Responsiveness for the step tests was evaluated in patients undergoing pulmonary rehabilitation (six-minute Step Test,[46] and six-minute Stepper Test),[36,37,43,50,52,56–59] physical training program (three-minute Step Test,[48] and six-minute Step Test[45,47]), pharmacological treatment – bronchodilator (three-minute Step Test[49]), physical activity counseling program (two-minute Step Test),[44] and photobiomodulation therapy (six-minute Stepper Test[51]). However, only the six-minute Stepper Test presented appropriate statistical analysis in two articles,[36,37] according to the correlations between the changes in the number of steps and changes in the six-minute walk test (distance) in pulmonary rehabilitation.

The data available on the interpretability of the step tests are presented in Table 3.

The methodological quality of each article, and the quality of each measurement property included in this review are presented in Supplemental Appendix 4.

Discussion

This systematic review identified nine step tests and showed that the level of evidence of their measurement properties for assessing the exercise capacity in people with chronic obstructive pulmonary disease is mostly “low” and “very low.” According to the modified Grading of Recommendations Assessment, Development, and Evaluation approach, the main reasons for these ratings were based in the small samples of participants included in the articles, and the presence of one or multiple articles of “inadequate” methodological quality.[15] However, despite our great effort to rate the methodological quality of the articles, we cannot assume these results as an absolute result, considering that we included studies that reported results for the measurement properties of the tests even if they were not specifically designed for it.

In general, reliability and responsiveness were the measurement properties with the worst level

Table 2. Level of evidence synthesis of measurement properties of the step tests.

Test	Criterion validity		Construct validity		Reliability		Measurement error		Responsiveness	
	Result	Level of evidence	Result	Level of evidence	Result	Level of evidence	Result	Level of evidence	Result	Level of evidence
CST	$r = 0.69$ (-)	Low[1]	$r = 0.60–0.83$ (+)	Low[1]	ICC = 0.99 (+)	Very low[2]	(?)	Very low[2]		
MIST	(?)	Very low[2]			ICC = 0.93–0.99 (+)	Low[1]	(?)	Very low[1,3]		
2MST									NA	Very low[2]
3MST			$r = 0.78$ (+)	Moderate[1]	ICC = 0.96 (+)	Very low[2]	(?)	Very low[2]	NA	Very low[4]
4MST										
6MST			$r = 0.76$ (+)	Low[1]	ICC = 0.94–0.98 (+)	Very low[4,5]	(?)	Very low[4]	NA	Very low[4]
Paced step test	$r = 0.75$ (+)	Low[1]								
Step test protocol					ICC $>$ 0.91 (+)	Low[1]	(?)	Low[1]		
6MSpT	$r = 0.36–0.69$ (–)	Moderate[6]	$r = 0.56–0.71$ (+)	High	ICC = 0.91–0.94 $r = 0.92–0.95$ (+)	Very low[2]	(?)	Very low[2]	$r = 0.26–0.34$ (-)	Moderate[6,*]

CST: Chester step test; MIST: modified incremental step test; 2MST: two-minute step test; 3MST: three-minute step test; 4MST: four-minute step test; 6MST: six-minute step test; 6MSpT: six-minute stepper test. Reasons that justify the score, according to the modified GRADE approach: [1]small sample of participants included $\leqslant$50; [2]one study of inadequate quality available; [3]the rating of the measurement property was indeterminate; [4]multiple studies of inadequate quality available; [5]inconsistency; [6]the overall rating of the measurement property was insufficient.
*This level of evidence, and the respective summary result, were only considered for pulmonary rehabilitation, as it is the only intervention with articles with adequate statistical analysis, according to the Consensus-Based Standards for the Selection of Health Measurements Instruments.

Table 3. Interpretability of the step tests.

Test	Interpretability
MIST[33]	VO_2 (L) = –221.576 + [4.833 × number of steps] + [12.019 × body mass (kg)]
3MST[55]	VO_2 (L/min) = [0.015286 × body mass (kg)] + [0.035605 × step rate (steps/min)]–0.698449
4MST[54]	Cut-off of 65 steps, where higher values provide better prognostic, with mortality being significantly lower.
6MST[34]	Cut-off of 86 steps, where people with similar or lower values can be classified as low physical capacity.
6MSpT[37]	A MID of 20 steps (intervention: pulmonary rehabilitation).

of evidence, where most of the step tests presented "very low" rating, explained by the test-retest studies performed on the same day, the non-determination of the minimal important differences for measurement error, and only the use of the paired sample *T*-test or Wilcoxon signed-rank test for responsiveness.[15,21]

Another finding in our review was the heterogeneity found on the evidence available for the step tests, where some tests showed fewer results in isolated articles (Modified Incremental Step Test, two-minute Step Test, four-minute Step Test, Paced Step Test, and Step Test Protocol), which represents a weakness to determine their measurement properties. This poor quality of evidence reflects the lack of application of this type of exercise testing in evidence, and, consequently, in clinical practice, especially in the new models of pulmonary rehabilitation. Despite the proven benefits of the community- and home-based programs, the assessment of their results in exercise capacity outcome is still widely performed in a hospital or clinical setting, mostly with the field walking tests.[7,8] Given the example of the six-minute Stepper Test, this test gathers results for all the measurement properties and presents the best ratings for the level of evidence due to its large implementation not only in hospital settings[36,37,43] but also in home-based programs, where the assessment of its results was performed in the people' homes.[52] In fact, the "moderate" to "high" level of validity of the six-minute Stepper Test is reflected by the good correlations found with cardiopulmonary exercise testing, one-repetition maximum and the six-minute walk test, proven that this test can be an alternative to assess exercise capacity in people with chronic obstructive pulmonary disease. The same test was also rated as "moderate" responsiveness to pulmonary rehabilitation, due to the overall rating of the measurement property determined as "insufficient" ($r = 0.26–0.34$). This finding suggests a low correlation between the changes of the six-minute Stepper Test and the changes in the six-minute walk test, but one recommendation should be highlighted. The inclusion of the stepping as a type (mode) of exercise training could be an interesting option in endurance training, since the physiologic adaptations to exercise are specific to the type of exercise performed.[60] Thus, further studies on responsiveness should include this type of exercise training.

Another good rating was the "moderate" level of evidence on the construct validity of the three-Minute Step Test, due to its strong correlation with the six-minute walk test. In fact, despite the "low" ratings of level of evidence, other step tests that were compared with six-minute walk test (Chester Step Test, six-minute Step Test) also presented a consistent strong correlation. These correlations were mostly analyzed with performance variables of the tests (number of steps and six-minute walk distance), which support the conceptualization of these step tests as an important option to assess functional exercise performance.[61] This finding is supported by the fact that the measurement properties of the six-minute walk test qualify it as a more targeted test to assess functional exercise performance.[2,61] In fact, according to the step tests identified and their type of performance (self-paced, incremental, and/or constant work rate), we can assume that the different aims between the tests can reflect the assessment of different outcomes.

Given the example of the six- and three-minute Step Tests, these ones are clearly stepping versions of the six-minute walking test, which they could provide more results about functional exercise performance. On the other hand, the step tests with an incremental profile (Chester Step Test and Modified Incremental Step Test), given the similarity of the aims with the shuttle walk test, could be also considered a symptom-limited maximal exercise capacity tests. However, the results in this review cannot fulfill these statements. Future research is recommended for the development of studies on validity of the step tests including cardiorespiratory response and the comparison with the gold standard tests for exercise capacity, and other physiological variables.

To the best of our knowledge, there is no review available in evidence that determined the level of evidence of the measurement properties of step testing in chronic respiratory diseases. Even so, the application of step testing has also been applied in other chronic respiratory diseases, with promising results, especially on validity. As an example, the Modified Incremental Test, Chester Step Test, three- and six-minute Step Test present good correlations mostly with the field walking tests in people with Bronchiectasis,[62,63] Interstitial Lung Disease,[28] and Asthma.[64] This is also the first systematic review that includes step tests using different equipment (step and stepper). Another strength of this review is the inclusion of studies that reported measurement properties of the test even if they were not specifically designed for it, which allowed us to identify a broad range of studies.

There were some study limitations. First, this systematic review only included articles written in English and Portuguese, which led to the exclusion of relevant studies. Second, during the literature search we found abstracts in congresses with potential measurement properties for step and stepper tests, but according to exclusion criteria these studies were not included. Another limitation refers to the involvement of one reviewer in the initial screening of articles, although two reviewers worked in close collaboration with several meetings throughout the selection process.

Future research is important to improve the level of evidence of the step tests, where future studies should be conducted following the recommendations of the Consensus-Based Standards for the Selection of Health Measurements Instruments to develop appropriate results.

In conclusion, the general level of evidence of the measurement properties of the step tests identified is "low" to "very low" for assessing exercise capacity in people with chronic obstructive pulmonary disease, which can limit their current application in clinical practice. On the available evidence, the six-minute Stepper Test is currently the most appropriate step test available. Future well-designed studies are necessary to improve the quality of the measurement properties of the step tests.

Clinical Messages

- The current level of evidence of the measurement properties of the step tests is "low" to "very low" for assessing exercise capacity in people with chronic obstructive pulmonary disease.
- Robust methods should be designed and implemented to get a higher quality of the measurement properties of the step tests.

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Author contributions

R.V. conceived and designed the project. R.V. write the review. R.V. and A.M.M. collected and analyzed the data. R.V., A.M.M., and C.C. wrote the paper. R.V. is responsible for quality control of the study.

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Supplemental material

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